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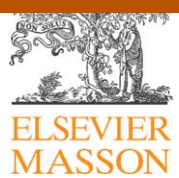

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ORIGINAL ARTICLE

Intermediate term functional outcome prediction following full thickness rotator cuff tear reparative or not reparative surgery

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KEYWORDS
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Fatty degeneration index

Summary Although simple suturing repair of a full thickness cuff tear can be performed when the preoperative fatty degeneration index (FDI) is 2 or less, it is not known if the functional results will be better than palliative surgical treatment.

The aim of this study is to describe and validate a method to predict the intermediate term unweighted Constant scores of different surgical treatments based on preoperative FDI. The hypothesis of this study is that the preoperative and final follow-up ratios FDI/final follow-up Constant scores regression lines, established on a previous ''reference study'' [5] (a series of 29 shoulders with cuff tears and sutured intact rotator cuff), could be used for this purpose.
Material: The present study included seven series of sutured cuffs (five, which resulted in intact cuffs and two in recurrent tears) and one series of cuffs treated with palliative surgery. Knowledge of the preoperative FDI and the location of the recurrent or unrepaired tears were required criteria for these series inclusion in the study.
Method: For each of the series in this study the Constant scores and selected score items were compared to scores calculated with the same mathematical formulas previously used to determine the regression lines in the reference study series (resulting in Constant scores in relation to preoperative and final follow-up FDI).
Results: The calculated Constant scores were similar to those reported by the authors, which validate the proposed method.

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Discussion: Because of the small size of the series of sutured cuffs with recurrent tears and of cuffs that underwent palliative surgery and arthroscopic treatment it is impossible to definitely confirm the validity of this method.
Conclusion: The intermediate term results of different surgical treatments can reasonably be predicted for full thickness tendon tears based on the preoperative FDI and the location of these tears. With this method the best treatment should be chosen for a rotator cuff tear on a case-by-case basis.
Level of evidence: Level IV.
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Introduction

The outcome of all types of surgical treatment for full thickness rotator cuff tears (successful/unsuccessful suture [1—7] or palliative surgery [8—10]) is always pain relief in the intermediate term. This pain relief is accompanied by improvement in active motion and the functional capacities of the shoulder.

Compared to palliative surgery, tendon-to-bone suture repair of supraspinatus tears associated with infraspinatus and/or subscapularis tears has the advantage of increasing shoulder strength and perhaps delaying the development of subacromial and glenohumeral osteoarthritis [2,5]. But gradual active movement of the shoulder cannot begin for at least 1 month after surgery due to the delay in tendon-bone healing, and several months are necessary before maximum function is obtained [11]. Moreover, with sutures there is a risk of recurrent tears although this rarely results in functional failures [7]. On the other hand, immediate active rehabilitation is possible with palliative surgery, and the patient can rapidly resume normal activities, which compensate for the residual weakness of the shoulder and the possible development of osteoarthritis [8]. Thus, when the FDI [1,3,12] of the rotator cuff is 2 or less, the choice of the type of surgical treatment is difficult because there is a good chance of obtaining an intact cuff with tension-free tendon-to-bone suture after excision of the macroscopically abnormal tendon lesions [3]. The study supported by the Haute Autorité de santé *française* [13] did not clarify the indications for these different treatments.

A recent study [5], which is called the ''reference study'' in the present paper, in a series of 29 sutured full thickness rotator cuff tears, which remained intact after a mean 8.9 years of follow-up with a standard deviation of ± 0.8 years and a range of 6.3 to 10 years, has shown that there is a strong correlation between the results of the Constant score and its different items [14] and the condition of the cuff muscles, evaluated according to the preoperative and final follow-up fatty degeneration index (FDI). The Constant scores at the final follow-up (which were similar to those obtained on the 28th month after surgery) did not depend on the age at final follow-up (67 ± 6.4 years, from 55.5 to 79 years old) — except for strength ($P = 0.0492$) — on the preoperative subacromial space (8.9 ± 1.9 mm, from 5—12 mm), on the number of sutured tendon tears (six times one tendon, 10 times two tendons and 13 times three tendons), on the suture technique (with — $n = 11$ — or without musculotendinous advancement) or on the association ($n = 17$) of the suture with acromioplasty or not.

The aim of this study is to describe and validate a method to predict the intermediate term Constant scores (before the possible development of osteoarthritis) for different surgical treatments of a specific rotator cuff tear. The hypothesis of this study was that the regression lines and their mathematical formulas (Table 1), obtained from the ''reference study'', could be used not only to predict successful suture results, but also, under certain conditions, recurrent tears after suture and palliative surgery results.

Materials

We searched the literature for series of full thickness rotator cuff tears that were surgically treated by suture or palliative surgery in which the intermediate term functional results were reported according to the unweighted Constant score and in which the preoperative fatty degeneration (FD) of the supraspinatus and subscapularis muscles was determined on MRI or CT scan according to Goutallier *et al*. grading [1,3]. Only the suture repair series, which evaluated postoperative anatomical results on CT arthrography or MRI were included in this study. If the cuff was intact after suture, only the preoperative FDI was necessary. If a recurrent tear occurred, only those series, which reported the location of the recurrent full thickness tears on the different tendons were included. In the palliative surgery series, only those, which reported the location of the full thickness tear on the tendons were included.

Eight series fit the inclusion criteria. There were five series of sutures by open surgery resulting in intact cuffs [1,3,4,6,15], and two series of sutures by open surgery resulting in recurrent cuff tears [3,4]. The eighth series [8] of palliative surgery was arthroscopic. This series was included even though only 228 of the 307 cases analysed were evaluated for FD. The number of shoulders in each series, the mean postoperative follow-up and the mean Constant scores and its items at the intermediate term follow-up reported by the authors are provided in Tables 2—4.

Methods

The mathematical formulas (Table 1) used to calculate in the reference series, the regression lines of the unweighted Constant scores and the scores of its main items (pain,

Table 1 Mathematical formulas to calculate the unweighted Constant scores (CST score) and those of their items based on preoperative and final follow-up fatty degeneration index (FDI) values.

	Regression lines CST score/preoperative FDI	Regression lines CST score/follow-up FDI
Unweighted Constant score	87.3-(11.7xFDI)	96-(15.2xFDI)
Pain	14.1-(1.4xFDI)	15-(1.7xFDI)
Motion	40-(3.8xFDI)	42.5-(4.7xFDI)
Strength	14.3-(4.7xFDI)	17.6-(6xFDI)

Table 2 Comparison of intermediate term unweighted Constant scores and those of their items reported by authors and calculated theoretical scores for cuffs sutured by open surgery without recurrent tears.

Authors	*n*	Preoperative FDI	Follow-up (years)	Results	Unweighted Constant score	Pain	Motion	Strength
Fuchs *et al.* [6]	10	1.2	3	Authors	73	11.8	—	11.8
				Calculated	73.3	12.5		8.6
Goutallier *et al.* [3]	22	1.14	2.6	Authors	75	12.3	34.8	10.9
				Calculated	74	12.5	35.6	8.9
Goutallier *et al.* [1]	141	0.5	3	Authors	78	—	—	—
				Calculated	81.4			
Postel *et al.* [4]	23	1.25	5	Authors	71	12.5	33.2	9.4
				Calculated	72.7	12.4	35.2	8.4
Gerber *et al.* [15]	8	1	1	Authors	76	—	—	11.4
				Calculated	75.6			9.6

Table 3 Comparison of intermediate term unweighted Constant scores and those of their items reported by authors and the calculated theoretical scores for cuffs sutured by open surgery with recurrent tears.

Authors	Number	Corrected FDI	Follow-up (years)	Results	Unweighted Constant score	Pain	Motion	Strength
Goutallier *et al.* [3]	4	1.8	2.5	Authors	64.5	12	31	6.5
				Calculated	66.2	11.6	33.1	5.8
Postel *et al.* [4]	6	3	5	Authors	63	10.5	31	8
				Calculated	52.2	10	28.5	0.1

motion, strength) in relation to the pre-operative FDI or the final follow-up FDI were applied to the series included in the study. The resulting scores were called the ''calculated theoretical scores'' and these were then compared to the ''real'' scores provided by the authors. It is interesting to note that the regression lines obtained with the preoperative FDI and those obtained with the final follow-up FDI could not be superimposed (Fig. 1) because of the increase (of a mean 0.3 points) of the FDI in the first year after surgery [5].

The preoperative FDI reported by the authors was used in the series of cuffs that were intact at final follow-up. The mathematical formulas to calculate regression lines in relation to the preoperative FDI were applied.

The preoperative FDI provided by the authors was recalculated (''corrected FDI'') in the series of cuffs with

Table 4 Comparison of intermediate term unweighted Constant scores and those of their items reported by authors and calculated theoretical scores, in unrepaired cuff tears.

Authors	Corrected FDI	Follow-up (years)	Results	Unweighted Constant score	Pain	Motion	Strength
Walch *et al.* [8]	1.8	3.8	Authors *n* = 307	67.6	11	35.3	6.4
			Calculated *n* = 228	68.6	12	34	6.8

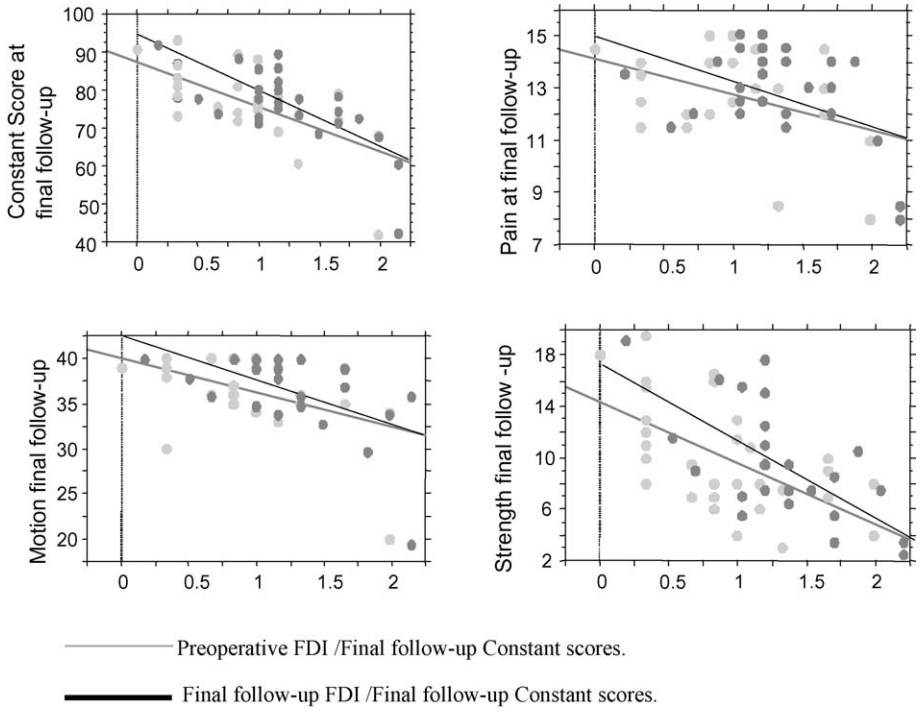

Figure 1 The regression lines of the preoperative FDI/unweighted Constant scores at final follow-up and the final follow FDI/unweighted Constant scores at final follow-up from the ''reference series'' are superimposed.

recurrent tears at follow-up, in order to take into account the recurrent tear. The corrected FDI was obtained by assigning an FD score of 3 to the muscle(s) involved in the recurrent tear, whatever the preoperative score for these muscle(s), because a muscle with a tendon tear can be considered a non-functioning muscle with an intact tendon [16]. The formulas to calculate regression lines in relation to the preoperative FDI were applied.

In the series of palliative treatment, the preoperative FDI reported by the authors was corrected in the same way as above, by assigning an FD score of 3 to tendon tears whatever their preoperative CT scan FD. Unlike the other two groups, the formulas to calculate the regression lines in relation to final follow-up FDI were applied. Indeed, although this has not been proven, we consider that palliative treatments, which allow immediate active motion result in little or no worsening of postoperative FD. Thus, there is no need to apply the formulas to calculate regression lines in relation to the preoperative FDI, which integrates the increase in the FDI after suture. This degeneration probably occurs because active motion must be delayed after surgical repair [5].

Table 5 Full thickness supraspinatus tears: comparison of calculated theoretical functional results (according to the Constant score) of successful sutures, sutures with recurrent full thickness supraspinatus tears and palliative treatment according to the different preoperative supraspinatus, infraspinatus and subscapular FD and the preoperative respective FDIs.

			Sutures Without recurrent tears					Sutures with recurrent full thickness supraspinatus tears					Palliative surgery				
Preoperative FD scan			FDI	Postoperative function (Constant score)				Corrected FDI	Postoperative function (Constant score)				Corrected FDI	Postoperative function (Constant score)			
s	i	ss		C	P	M	S		C	P	M	S		C	P	M	S
0	0	0	0	87	14	40	14	1	76	13	36	10	1	81	13	38	12
1	0	0	0.3	84	14	39	13	1					1				
2	0	0	0.7	79	13	37	11	1					1				

s: supraspinatus; i: infraspinatus; ss: subscapular; C: unweighted Constant score; P: pain; M: motion; S: strength.
The Constant scores were rounded off to the next highest tenth if the decimal was above 5 and the next lowest if it was below 5. The FD of muscles without tendon tears were graded 0. In cuffs with recurrent supraspinatus tears and cuffs without supraspinatus repair, the FDI were corrected because the FD of the supraspinatus was graded 3 whatever the preoperative FD on the scan.

Results

For seven of the eight series, the calculated theoretical values of the Constant score and its items were similar to the mean scores reported by the authors (Tables 2—4). In the eighth series of sutured cuffs with recurrent tears reported by Postel *et al.*, most of the calculated theoretical values were significantly lower than those reported by the authors. When the FDI is above 2.25, there is no more cuff function. In this case shoulder function is only ensured by muscles other than the rotator cuff resulting in a ''base'' Constant score of approximately 62 points with pain, motion and strength of approximately 11, 32 and 4 points respectively [17].

With the results of this study, the regression lines in the reference study can be applied to other series of surgical treatment of the rotator cuff, and the methods of correction of the FDI in relation to tendon tears and of choice of regression lines (in relation to preoperative or final follow-up FDI) have been validated.

Discussion

Eight series or parts of series in the literature on full thickness rotator cuff tears report the preoperative FD and FDI and the location of the full thickness tendon tears (five series of anatomically successful sutures, two series of sutures with recurrent tears and one series of palliative treatment) as well as the postoperative mean unweighted Constant scores and the scores of its items. These reported scores were compared to scores, which could be calculated theoretically from regression lines obtained from an analysis of a series of 29 sutured full thickness cuff tears that were intact after long-term follow-up [5]. These regression lines showed a strong negative correlation between preoperative and final follow-up FDI and final follow-up Constant scores. The method of calculating the ''theoretical'' Constant scores of successful suture repair, of sutures with recurrent tears, and of palliative surgery from the preoperative FDI has been described. The agreement between the scores reported by the authors of the eight series in the literature and the theoretically predicted scores seems to validate this method of determining predictive scores.

Nevertheless, this study has certain limits. Only a few series could be included because of the inclusion criteria, in particular studies on sutures with recurrent tears and palliative treatment. Our results are therefore insufficient to definitely confirm the validity of the method to calculate predictive scores. Because of our inclusion criteria, the series of successful or unsuccessful sutures only included studies with open surgery. We cannot be sure that regression lines in relation to the preoperative FDI in the reference study can be applied to endoscopic techniques, which may have a different effect on muscle degeneration, which, for the moment is unknown. The ''calculated theoretical values'' are only approximate. The ''calculated value'' of the Constant scores obtained from the FDI cannot be that of all shoulders having this FDI because of the distribution of the points around the regression lines. We cannot be certain that all cuff muscles have the same impact on the Constant score and its items. Another weakness of this study is

Table 6 Full thickness supraspinatus and infraspinatus tears: comparison of calculated theoretical functional results (according to the Constant score) of successful sutures, sutures with recurrent full thickness supraspinatus tears and palliative treatments in relation to the different preoperative FD of the supraspinatus, infraspinatus and subscapular muscles and the preoperative FDI.

			Sutures without recurrent tears				Sutures with recurrent full thickness supraspinatus tears				Palliative surgery					
Preoperative FD scan			FDI	Post operative function (Constant score)				Corrected FDI	Post-operative function (Constant score)			Corrected FDI	Postoperative function (Constant score)			
s	i	ss		C	P	M	S		C	P	M	S		C	P	M	S
0	0	0	0	87	14	40	14	1	76	13	36	10	2				
1	1	0	0.7	79	13	37	11	1.3	72	12	35	8	2	66	12	33	6
2	1	0	1	76	13	36	10	1.3					2				
2	2	0	1.3	72	12	35	8	1.7	67	12	33	6	2				
3	2	0	1.7	67	12	33	6	1.7					2				

s: supraspinatus; i: infraspinatus; ss: subscapular; C: unweighted Constant score; P: pain; M: motion; S: strength.
The Constant scores were rounded off to the next highest tenth if the decimal was above 5 and the next lowest if it was below 5. The FD of muscles without tendon tears were graded 0. In cuffs with recurrent supraspinatus tears and unrepaired cuffs, the FDI were corrected because the FD of the supraspinatus with recurrent tears after suture and unrepaired supraspinatus and infraspinatus were graded 3 whatever the preoperative FD on the scan.

Table 7 Full thickness tear of the three tendons: comparison of calculated theoretical functional results (based on the Constant score) of successful sutures, sutures with recurrent full thickness supraspinatus tears, and palliative surgery in relation to the different preoperative FD of the supraspinatus, infraspinatus and subscapular muscles and the preoperative FDI.

Preoperative FD scan			Sutures without recurrent tears					Sutures with full thickness supraspinatus tears					Palliative surgery				
			FDI	Postoperative function (Constant score)				Corrected FDI	Postoperative function (Constant score)				Corrected FDI	Postoperative function (Constant score)			
s	i	ss		C	P	M	S		C	P	M	S		C	P	M	S
0	0	0	0	87	14	39	14	1	76	13	36	10	3	62[a]	11[a]	32[a]	4[a]
1	1	1	1	76	13	36	10	1.7	67	12	33	6	3				
2	1	1	1.3	72	12	35	8	1.7					3				
2	2	1	1.7	67	12	33	6	2	64	11	32	5	3				

s: supraspinatus; i: infraspinatus; ss: subscapular; C: unweighted Constant score; P: pain; M: motion; S: strength.
The Constant scores were rounded off to the next highest tenth if the decimal was above 5 and the next lowest if it was below 5. The FD of muscles without tendon tears were graded 0. In cuffs with recurrent supraspinatus tears and unrepaired cuffs, the FDI were corrected because the FD of the supraspinatus with recurrent tears after suture and unrepaired supraspinatus, infraspinatus and subscapularis muscles were graded 3 whatever the preoperative FD on the scan.
[a] Base ''constant scores''.

that it did not take into account preoperative muscular atrophy, although there is a correlation, for the supraspinatus at least, between muscular atrophy and fatty degeneration [15,18]. The reproducibility of the evaluation of muscular FD seems to be confirmed in a recent study [19] as long as the evaluator is experienced, which was already mentioned in a previous study, especially for the FDI [20]. The use of regression lines for the FDI, which is a semi-quantitative variable, can be contested. Nevertheless, the ''calculated theoretical values'' of the Constant scores in relation to the preoperative FDI are very similar to those reported by the authors.

The prediction of functional results based on the preoperative FDI could be used to compare the potential intermediate term results of different surgical treatments for specific full thickness cuff tears (Tables 5—7).

- Good Constant scores (between 76 and 87 points), good pain relief (between 13 and 14 points) and good active motion can be predicted for isolated total full thickness tears of the supraspinatus (Table 5), whatever the treatment and whatever the preoperative non corrected FDI. Strength is more apt to vary (between 10 and 14 points) depending on the type of treatment. The Constant score will be better in a successful suture if the non corrected FDI is 0.3 or less. Results of palliative treatment will be slightly better than suture in the case of a recurrent total full thickness supraspinatus tear;
- If the preoperative non corrected FDI is less than 1 in cases of total full thickness supraspinatus and infraspinatus tears (Table 6) as well as in total full thickness tears of the three tendons (Table 7), we can predict that the results of successful suture will be better than those of suture with a recurrent total full thickness supraspinatus tear or of palliative treatment. The results of suture with a recurrent total full thickness supraspinatus tear will be better than palliative treatment if the non corrected FDI is less than 1.3. But whatever the FDI or the treatment, there will be little pain (12 or above) except with palliative treatment of tears of the three tendons.

It is possible that the predictions of the functional results of ''medical'' treatments obey the same rules as those of palliative surgical treatments. Unfortunately, the lack of information on the exact tendon tears and the FD of the muscles in the series in the literature make it impossible to validate this hypothesis.

Conclusions

The aim of this study is reached: the regression lines obtained in the ''reference study'' could be used to predict the intermediate term (before the development of osteoarthritis) functional results (evaluated by the unweighted Constant scores) of successful sutures, sutures with recurrent tears and palliative treatment for full thickness rotator cuff tears.

In this way, the predicted intermediate term results of the different surgical treatments of a specific rotator cuff tear can help to choose the best adapted to the patient's expectations (merely functional shoulder, or the strongest

shoulder possible, with the greatest active ROM) taking into account the patient's age, and ability to comply to postoperative follow-up procedures. Other studies are needed to confirm the value of this method to predict the functional results of the different procedures, especially sutures with recurrent tears and palliative treatment. It is also necessary to confirm that palliative treatment, which allows nearly immediate active motion does not significantly increase the FDI, and that arthroscopic suture, which limits active motion for 1 month after surgery, increases FD and the FDI like open surgery. These new studies must be performed in series in which tendon tears are clearly described and evaluation of muscle FD is performed according to standardized protocols.[1,3].

Conflict of interest statement

None.

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